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REPORT OF FINDINGS: INNOKO NATIONAL WILDLIFE REFUGE PLACER MINING STUDY

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INTRODUCTION

The Innoko National Wildlife Refuge (Refuge) was established in 1960 with the passage of the Alaska National Interest Lands Conservation Act. It covers approximately 3,850,000 acres in west-central Alaska (Figure 1). Purposes of the refuge under the Act include:

(i) to conserve fish and wildlife populations and habitats in their natural diversity including, but not limited to, waterfowl, peregrine falcons, other migratory birds, black bear, moose, furbearers, and other mammals and salmon. . . .

(ii) to ensure, to the maximum extent practicable and in a manner consistent with the purposes set forth in paragraph (i), water quality and necessary water quantity within the refuge.

Placer mining has occurred in the headwaters of the Innoko River drainage since the early 1900's. A rise in gold prices in the early 1970's caused a dramatic increase in mining activity. In general, placer mines in Alaska have had a history of non-compliance with water quality standards, particularly with respect to turbidity and settleable solids. Regulators have in the past considered stream reclassification as a method of remedying the situation of non-compliance with water quality standards on those streams that are the most heavily mined. This approach of changing regulations to fit the needs of the industry would cause further degradation of downstream (refuge) water quality. While most of the mining activity occurs some distance from the refuge boundaries (see Figure 2), there is a concern that these activities, or new mining in streams not currently affected, would cause a deterioration in refuge water quality.

Initial and preliminary grab sampling efforts in 1985 and 1986 (not replicated) indicated that turbidity, copper, zinc and mercury may be elevated. With this concern in mind the Refuge staff decided to determine the background levels of metals in water, sediment, (and a few fish) from selected drainages on the Refuge. A structured monitoring effort was commenced at 12 sites in 1987. Water quality was monitored by establishing sampling points on each of the tributaries of the Innoko River. Inferences as to past quality are allowed by results of bottom samples taken at the same points. Preliminary samples of fish tissue were taken to establish a crude baseline for 1987.

John DeLapp, from the Refuge, conducted the 1985-1988 field efforts. Dr. Rodney Jackson, from the Ecological Services Anchorage office, interpreted the 1987-88 data and authored this report.

Figure 1. Location of Innoko Refuge.

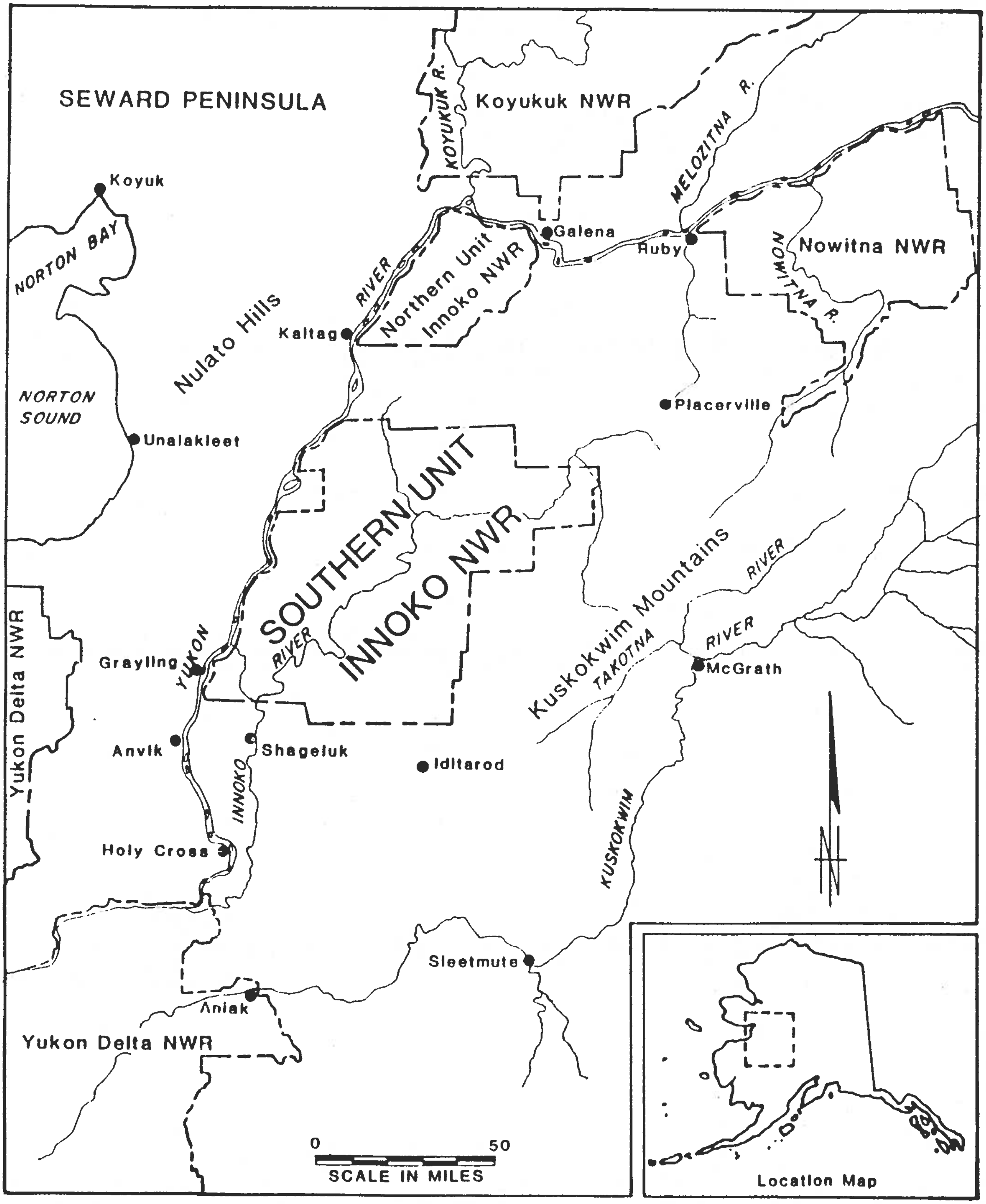
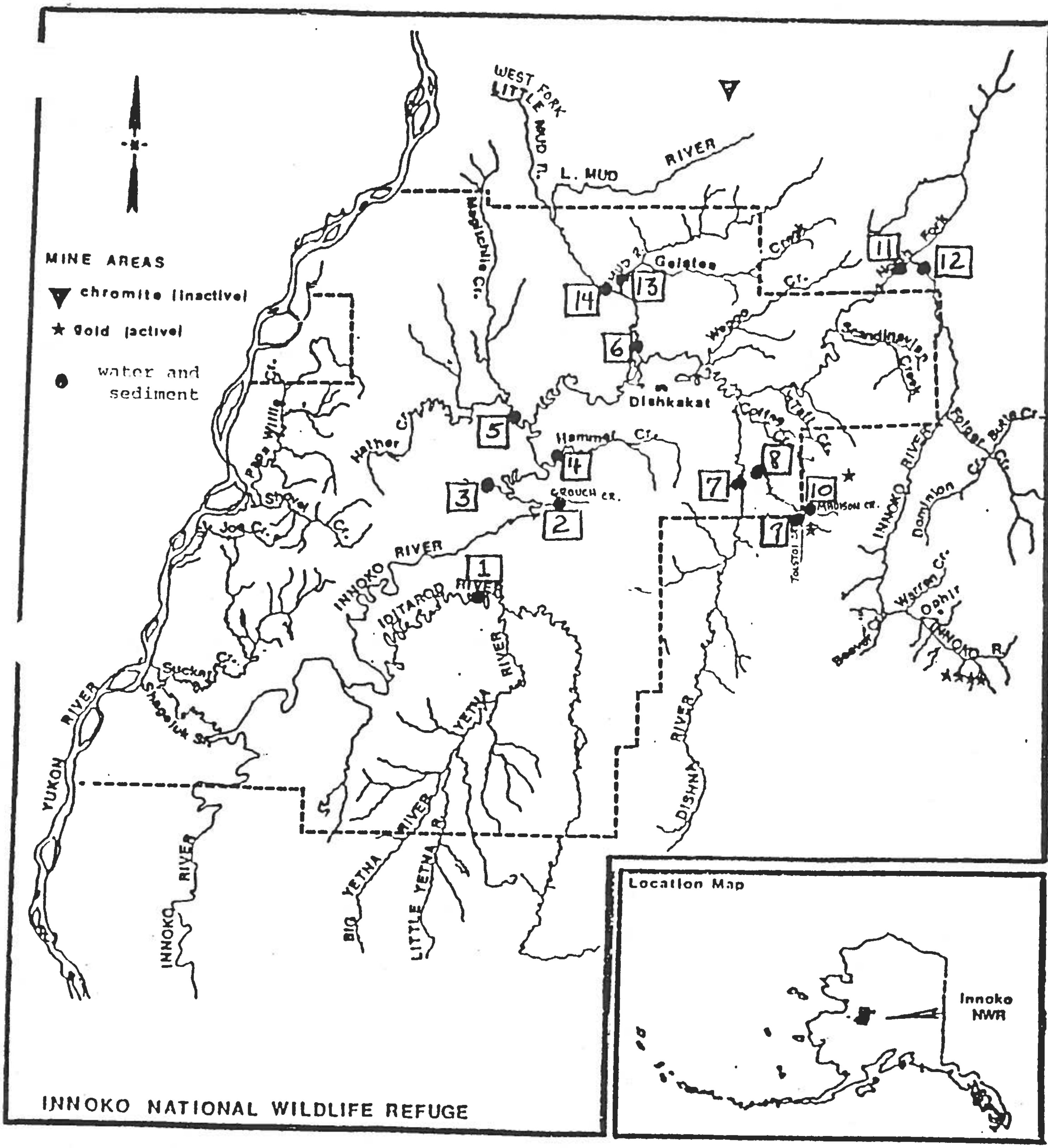


Figure 2. Sample Site Locations.



Study Area

Figure 2 shows the general location of the Refuge, mining areas and the sample sites. Sample sites 1, 8, 9, 10, 11, and 12 are downstream of mined areas. All other sites serve as controls (for relative comparisons).

Field Procedures

At each site three replicate water samples were taken for recoverable metals; one water sample was taken for total metals analyses. All water samples were placed in 250-ml, acid-cleaned, polyethylene jars with Teflon-lined covers; preserved immediately with nitric acid to a pH of less than 2; and refrigerated until analyses.

At each site three replicate sediment samples (each a composite of three to five grabs) were taken for total metals analyses. All samples were placed in 250-ml, polyethylene jars with Teflon-lined covers, and refrigerated until analyses.

All fish (northern pike) were collected with a gill net or with hook and line; fillets for tissue samples were removed from the upper dorsal side with a steel fillet knife, and the skinned fillets were placed in individual, doubled, zip-lock bags and frozen.

Analytical Procedures

Standard techniques of atomic absorption and inductively coupled plasma spectrometry were utilized by Hazelton Laboratories (1987 data) and the Research Triangle Institute (1988 data) to determine concentrations of metals. The quality assurance report of the U.S. Fish and Wildlife Service's Patuxent Laboratory stated that the accuracy of all analyses were generally acceptable; however, the confidence is low for antimony, silver and tin (1988 data only) due to their low recovery.

RESULTS

Complete sets of raw data are on file at the Innoko National Wildlife Refuge and the Ecological Services Anchorage offices. All raw data for 1987 and 1988 are tabulated by element in Appendix B.

Data Interpretation

The process of interpreting chemical analyses is aimed at addressing the question "Do the sample data indicate a problem exists?" In its simplest form this act would appear to consist of comparing each sample datum with a list of action levels or threshold levels (= criteria), above which a problem - albeit undefined - exists. Indeed, this would be ideal. However, a variety of problems impede this approach.

In the case of water and soil/sediment, the total amount of a chemical reported for a sample is not synonymous with the amount that is (biologically) available. The latter is strongly influenced by a complex suite of physical, chemical and biological factors (e.g. pH, Eh, hardness, alkalinity, salinity, concentration of organic matter, texture). One never has all relevant information for each sample that would allow adjustment of calculated values prior to comparison with a list of criteria (Long and Morgan, 1990; Shea, 1988).

In the case of tissue samples, a different criterion may exist for each species, as well as the particular tissue within that species (e.g. liver vs. kidney vs. muscle vs. whole body homogenate). Moreover, a sublethal criterion (e.g. avoidance, impaired growth, impaired reproductive success) is much lower than a criterion for safe consumption levels or acute mortality. These and other problems with developing a single set of rigid criteria are thoroughly discussed in Long and Morgan (1990) and Soholt, et al (1981). Nevertheless, an arbitrary set of criteria has been subjectively constructed by amalgamating a variety of information including: Environmental Protection Agency's water quality criteria; review papers/series that offer lists of "action levels;" U.S. Food and Drug Administration's action levels for poisonous or deleterious substances in human food; World Health Organization's list of water quality criteria; and sundry literature dealing with some sort of biological effect of one, a few, or a group of individual chemicals. As many of the above sources as time allowed were reviewed prior to finalizing the criteria (Appendix A).

The approach to interpretation consists of a 4-step process, essentially comparing each laboratory-reported value to a series of screens:

1. Background or control samples taken from the study area

2. The subjective set of criteria (Appendix A)

3. Literature values listing averages and ranges for Alaska (Gough, et. al, 1988)

4. Literature values listing averages and ranges on a worldwide basis (Fortescue, 1980)

In general, we did not consider a sample value problematical unless it exceeded one order of magnitude of the appropriate screen(s). This is a common strategy designed to provide a buffer for a variety of sources of inherent variance, principally site specificity and laboratory methodology.

In addition to comparing raw data to action levels, appropriate control sites (unmined streams) were compared to sites on mined streams within a given year. Trends were examined by comparing appropriate sets of 1987 and 1988 data.

Exceedance of Action Levels

Table 1 lists those instances where either a single replicate (or the average of three) exceeded action levels for sediment. Table 2 does the same for water samples.

Sediment. No element exceeded its action level in 1987 data. Average chromium concentrations in 1988 were high; however, all stations except number 14 exceeded action levels. This is a strong indication that an artifact is the cause. Manganese and nickel had individual samples exceeding the action level in 1988, but average concentrations did not exceed the action level. In no case did any site exceed the action level by an order of magnitude or greater.

Water. Table 2 reveals that some water action levels were exceeded, primarily in 1988. Samples at site 3, located on an unmined stream, contained elevated levels of chromium, zinc and tin. Samples at site 12, downstream of mining activities, contained elevated aluminum. In no case did any site exceed the action level by an order of magnitude or greater.

Tissue Analyses

Single samples were available for one year only; hence, comparisons were limited to visual examination of raw data (Appendix B). Action levels were exceeded for two metals: mercury and chromium. Mercury is a potential metal of concern due to it's high absolute concentrations - in controls as well as fish from mined streams. Eisler (1987) proposed 1.0 ppm mercury be used as a criterion for edible portions of fish. Two control and two experimental samples exceeded this level to a slight degree (see Appendix B). Eisler (1986) proposed 4.0 ppm (dry weigh) chromium as a human health criterion for fish muscle tissue. This concentration was exceeded in only one sample - (INNT07). Chromium, copper, iron, nickel and zinc are somewhat elevated (relative to controls) in sample INNT07; copper and iron are somewhat elevated in INNT08. No other relative differences are obvious.

Within-year Comparisons

Several comparisons were made in order to determine if (1) significant contamination had occurred prior to initial sampling, and (2) obvious trends existed. For 1987 and 1988 data (separately), appropriate sites on unmined streams (controls) were visually - not statistically - compared to relevant site(s) downstream of mining activities. In addition, some controls were compared to each other. These ocular examinations are summarized in Tables 3 and 4. There are scattered incidences where one or a few elements are relatively elevated in either sediment or water samples. However, an element was rarely elevated in both water and sediment at a given site. No element appeared consistently elevated, and no strong trends were apparent.

CONCLUSIONS AND RECOMMENDATIONS

In general the study area appears to have relatively high background concentrations of several metals, especially chromium, zinc, nickel, and possibly aluminum. In scattered samples, several of the trace metals appear to be in high concentrations, but these are often in control sites. Sites 3 and 5 appear to be the most elevated of the control sites (for sediment and water). As noted earlier in this report, the high chromium sediment levels in 1988 data are possibly artifacts; this supposition is likely accurate given the uniformly high concentrations of chromium.

Comparisons of sediment and water data for mined streams with appropriate controls yield no significant differences (for either year). Comparisons of 1987 versus 1988 data for each site yield no uniform trends. Although tissue mercury levels appear elevated, it does not appear to be caused by mining activities (elevations occur in controls as well as experimentals). One sample of tissue chromium appears elevated, but it does not appear to be cause for concern. It must be emphasized that these conclusions are based on a small set of data.

In no case did any site exceed the sediment or water action level by an order of magnitude. Thus there is no evidence of gross contamination requiring immediate action. It will be prudent to conduct additional monitoring on a regular schedule (every two or three years). The frequency of sampling should be adjusted to reflect the degree of mining activity that may affect refuge resources. Prior to future sampling, your staff must submit a study plan to the Regional Contaminants Coordinator to secure funding.

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Table 1. Elements Exceeding Action Level - Sediment

Site		Elements (Year)		
1	mined	Cr(88)*		
2	control	Cr(88)*		
3	control	Cr(88)*	Fe(88)	Ni(88)
4	control	Cr(88)*		
5	control	Cr(88)*		
6	control	Cr(88)*		
7	control	Cr(88)*		
8	mined	Cr(88)*		
9	mined	Cr(88)*		
10	mined	Cr(88)*		
11	mined	Cr(88)*		
12	mined	Cr(88)*		
13	control	Cr(88)*		
14	control	none		

* Indicates that the average of three samples exceeded the action level. Lack of an asterisk indicated only one value in a set exceeded the action level.

Table 2. Elements Exceeding Action Level - Water

Site[a]	Elements (Year)						
1 m			none				
2 c			none				
3 c			Cr(88)*		Ni(88)	Zn(88)	Sn(88)*
4 c						Zn(88)	
5 c			Cr(88)			Zn(88)	Sn(88)
6 c				Cu(88)			
7 c		Cd(88)					
8 m						Zn(88)	
9 m			none				
10 m			none				
11 m	Al(87)						
12 m	Al(87)*						
13 c			none				
14 c						Zn(88)	

[a] m denotes site is on a mined stream; c denotes control (unmined)

* indicates that the average of three samples exceeded the action level. Lack of an asterisk indicates only one value in a set exceeded the action level.

Table 3. Summary of Ocular Comparisons - 1987 Data

Sites Compared	Apparent Elevations (sediment)	Apparent Elevations (water)
2,3,4,5 (controls) vs. 1 (mined)	Mn	-
7 (controls) vs. 8 (mined)	-	-
7 (controls) vs. 9 (mined)	-	-
7 (controls) vs. 11 (mined)	Cd	Al, Fe, Mn
7 (controls) vs. 12 (mined)	Cd	Al, Fe, Mn
6,13,14 (controls) vs. 11 (mined)	Mn	Al
6,13,14 (controls) vs. 12 (mined)	-	Al
6 vs. 13 vs. 14 (all controls)	no obvious differences	
11 (mined) vs. 12 (mined)	sediment levels of 11 are relatively high	

Table 4. Summary of Ocular Comparisons - 1988 Data

Sites Compared	Apparent Elevations (sediment)	Apparent Elevations (water)
2,3,4,5 (controls) vs. 1 (mined)	-	-
7 (controls) vs. 8 (mined)	-	-
7 (controls) vs. 9 (mined)	Cu, Mn, Sn	-
7 (controls) vs. 10 (mined)	Se	-
7 (controls) vs. 11 (mined)	-	Al
7 (controls) vs. 12 (mined)	Cu, Se	Al
6,13,14 (controls) vs. 11 (mined)	-	-
6,13,14 (controls) vs. 12 (mined)	Cu	-
6 vs. 13 vs. 14 (all controls)	6 and 13 relatively high in most elements	
11 (mined) vs. 12 (mined)	most elements in 12 are higher (opposite found in 1987 data)	

Appendix A. Action Levels : Metals

ELEMENT	CRITERIA[a]	
	Water[b]	Soil/Sediment[b]
Aluminum	400.0 (F);10.(M)	81000.(F)
Antimony	0.6 (F)	9.0
Arsenic	0.1 (F); 0.02 (M)	64.0
Barium	------	430.
Beryllium	50.0 (F)	15.0
Boron	12.0 (F)	100.
Cadmium	0.003 (F); 0.009 (M)	6.0 (F); 9.0 (M)
Chromium	0.03 (F); 1.2 (M)	37.0 (F); 128.(M)
Copper	0.01 (F); 0.005 (M)	310.
Lead	0.02 (F); 0.01 (M)	50.0 (F); 104.(M)
Manganese	7.0 (F); 2.0 (M)	1000.
Mercury	0.002 (F); 0.0003 (M)	20.0 (F); 1.0 (M)
Molybdenum	50.0 (F)	100.
Nickel	0.3 (F); 2.0 (M)	100.
Selenium	0.3 (F); 0.4 (M)	10.0
Silver	0.001 (F); 0.01 (M)	2.1
Tin (inorganic)	0.05 (F); 0.3 (M)	200.
(tributyl)	0.00001 (F)	---
Vanadium	1.0 (F); 1.0 (M)	150.
Zinc	20.0 (F); 5.0 (M)	200. (F); 267. (M)

[a] All concentrations are in ppm. Subjective criteria were chosen using best professional judgment after consulting references listed at the end of this appendix. In general, a sample value greater than 10 times a criterion can be cause for concern.

[b] (F) = freshwater; (M) = marine

Fish and Wildlife Service
Ecological Services Anchorage
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APPE DIX B. Raw Data' for Innoko VR Placer Mining Study - 198. 1988

Site No.	Sample ID	As 1988	As 1987	Sb 1988	Sb 1987	Hg 1988	Hg 1987	Al 1988	Al 1987	Cd 1988	Cd 1987	Cr 1988	Cr 1987	Cu 1988	Cu 1987	Fe 1988	Fe 1987	Pb 1988	Pb 1987	Mn 1988	Mn 1987	Ni 1988	Ni 1987	Zn 1988	Zn 1987	Se 1988	Se 1987	Ag 1988	Ag 1987	Sn 1988	Sn 198.
2	AIN02S	2.76	8.58	ND	.23	0.2	.11	8150	17400	ND	1.23	94.1	35.7	12.0	25.0	35900	27500	13.1	ND	462.	335	38.3	28.4	100.	82.1	.35	.32	ND		64.6	
	BIN02S	6.95	8.46	ND	.28	0.2	.11	16900	16800	ND	1.90	78.0	34.7	12.3	20.4	35400	26900	12.9	ND	458.	326	33.5	28.0	92.5	74.8	.38	.38	ND		ND	
	CIN02S	2.21	9.46	ND	.31	0.1	.14	7050	18200	ND	1.48	79.3	36.2	6.9	23.3	30900	30300	ND	ND	465.	353	35.5	30.9	86.3	95.9	.49	.40	ND		ND	
	AIN02TW	ND	.002	ND	ND	ND	ND	0.80	.25	.001	ND	.006	ND	.002	ND	6.4	3.1	ND	ND	.22	.05	.008	.010	.025	ND	ND	ND	ND		ND	
	AIN02RW	ND	.001	ND	ND	ND	ND	.46	.22	ND	ND	.006	ND	ND	ND	9.5	2.4	ND	ND	.35	.04	.006	ND	.022	ND	ND	ND	ND		ND	
	BIN02RW	ND	.002	ND	ND	ND	ND	.46	.24	ND	ND	.003	ND	.002	ND	3.2	2.8	ND	ND	.11	.05	.009	ND	.021	ND	ND	ND	ND		ND	
	CIN02RW	ND	.002	ND	ND	ND	ND	.66	.29	ND	ND	.005	ND	ND	ND	7.1	3.4	ND	ND	.29	.06	.006	.020	ND	ND	ND	ND	ND		ND	
3	AIN03S	12.7	17.9	ND	.18	ND	.08	7040	13500	ND	ND	88.0	25.9	11.9	29.4	43200	33500	16.4	36.3	623.	391	39.0	34.9	106.	76.9	.67	.30	ND		47.3	
	BIN03S	10.4	14.3	ND	.19	.08	.09	15900	13500	ND	ND	125.	26.3	17.6	28.8	46500	28100	20.6	29.0	965.	324	57.9	30.2	154.	79.7	.52	.30	ND		ND	
	CIN03S	11.9	13.3	ND	.30	.08	.08	13300	11600	ND	ND	82.9	22.4	9.5	20.0	42500	24200	15.0	31.5	632	256	38.2	25.9	102	66.4	.73	.28	ND		ND	
	AIN03TW	ND	.003	ND	ND	ND	ND	.23	.33	ND	ND	.076	.004	.010	ND	6.9	6.2	ND	ND	.18	.09	.094	ND	.032	.013	ND	ND	ND		.10	
	AIN03RW	ND	.003	ND	ND	ND	ND	.16	.23	ND	ND	.125	.005	.010	ND	3.2	3.4	ND	ND	.08	.05	.089	ND	.035	.011	ND	ND	ND		.12	
	BIN03RW	ND	.004	ND	ND	ND	ND	.19	.25	ND	ND	.066	.006	.004	ND	4.2	3.6	ND	ND	.10	.05	.046	ND	.101	ND	ND	ND	ND		.05	
	CIN03RW	ND	.001	ND	ND	ND	ND	.23	.27	.001	ND	.004	.004	.003	ND	5.3	4.3	ND	ND	.14	.07	.009	ND	.041	.009	ND	ND	ND		.02	
4	AIN04S	7.1	8.9	ND	.22	.07	.08	5710	13700	ND	ND	43.2	14.6	7.2	25.5	18300	24100	ND	ND	233.	241	18.3	25.0	54.7	73.2	.70	.29	ND		ND	
	BIN04S	4.9	9.9	ND	.24	.08	.18	10000	14400	ND	ND	83.1	28.2	12.2	25.8	30000	26300	14.4	ND	423.	270	32.3	26.5	99.1	83.7	ND	.29	ND		ND	
	CIN04S	7.6	9.3	ND	.22	.10	.10	9270	11900	ND	ND	83.3	22.3	9.2	20.9	34200	23300	ND	32.2	408.	223	36.2	11.3	95.6	68.1	.50	.28	ND		ND	
	AIN04TW	ND	.004	ND	ND	ND	ND	.44	.56	ND	ND	.005	.005	.003	ND	8.3	3.6	0.01	ND	.34	.06	.005	ND	.043	.022	ND	ND	ND		ND	
	AIN04RW	ND	.002	ND	ND	ND	ND	.50	.56	ND	ND	.005	.006	ND	ND	9.1	4.1	ND	ND	.37	.07	.004	ND	.029	.010	ND	ND	ND		.01	
	BIN04RW	ND	.002	ND	ND	ND	ND	.43	.60	ND	ND	.005	.006	ND	ND	8.6	4.7	ND	ND	.35	.08	.006	ND	.038	.010	ND	ND	ND		ND	
	CIN04RW	ND	.004	ND	ND	ND	ND	.36	.66	.001	ND	.004	.006	ND	ND	5.0	6.7	ND	ND	.20	.11	.004	ND	.068	ND	ND	ND	ND		ND	
5	AIN05S	4.42	6.77	ND	.21	.07	.13	11500	11000	ND	ND	73.4	8.1	9.2	24.9	30900	17800	16.9	ND	494.	226	30.7	20.2	99.2	62.0	ND	.30	ND		52.9	
	BIN05S	3.14	5.86	ND	.22	.07	.11	11300	12100	ND	ND	73.0	19.5	12.2	23.8	28200	18900	ND	29.2	474.	231	26.0	14.6	94.2	61.0	.31	.28	ND		ND	
	CIN05S	2.92	5.58	ND	.20	.08	.10	6510	12100	ND	ND	68.8	10.9	8.7	21.8	29600	19200	21.9	ND	449.	246	31.4	24.3	85.1	65.0	ND	.26	ND		ND	
	AIN05TW	ND	.003	ND	ND	ND	ND	.46	.65	.002	ND	.006	.004	.003	ND	5.1	3.9	0.01	ND	.10	.06	.042	.013	.041	ND	ND	ND	ND		ND	
	AIN05RW	ND	.003	ND	ND	ND	ND	.30	.62	ND	ND	.014	.004	.002	ND	3.4	3.5	ND	ND	.07	.06	.011	ND	.116	.005	ND	ND	ND		.01	
	BIN05RW	ND	.004	ND	ND	ND	ND	.44	.78	ND	ND	.018	.003	.003	ND	4.5	6.2	ND	ND	.09	.10	.015	ND	.039	.006	ND	ND	ND		.02	
	CIN05RW	ND	.002	.02	ND	ND	ND	.39	.71	ND	ND	.052	.004	.005	ND	3.5	3.8	ND	ND	.08	.06	.026	ND	.036	.007	ND	ND	ND		.05	
1	AIN01S	4.78	16.0	ND	.29	.19	.13	8590	14500	ND	ND	79.9	18.5	7.9	24.8	30100	29800	ND	ND	435	647	36.8	29.6	83.7	79.5	.30	.33	ND		ND	
	BIN01S	8.13	14.6	ND	.34	.14	.14	8220	15100	ND	ND	77.7	22.1	9.0	23.1	32100	30200	12.4	31.0	509	575	36.7	22.5	89.9	83.2	.36	.40	ND		ND	
	CIN01S	8.76	13.8	ND	.27	.12	.15	8660	15100	ND	ND	86.8	28.8	13.1	25.4	36600	30800	15.4	ND	492	621	38.2	32.5	109.	85.5	ND	.41	ND		ND	
	AIN01TW	ND	.002	ND	ND	ND	ND	.80	.29	ND	ND	.004	ND	ND	ND	5.8	1.8	ND	ND	.13	.03	ND	ND	.022	ND	ND	.001	ND		ND	
	AIN01RW	ND	.001	ND	ND	ND	ND	.50	.29	ND	ND	.003	ND	ND	ND	5.2	1.6	ND	ND	.13	.02	ND	ND	ND	ND	ND	ND	ND		ND	
	BIN01RW	ND	.002	ND	ND	ND	ND	.74	.40	ND	ND	.003	ND	ND	ND	5.9	1.9	ND	ND	.14	.03	ND	ND	.023	.008	ND	ND	ND		ND	
	CIN01RW	ND	.001	ND	ND	ND	ND	1.06	.42	ND	ND	.004	ND	ND	ND	5.7	1.8	ND	ND	.13	.03	.009	ND	.030	ND	ND	ND	ND		ND	
6	AIN06S	10.2	11.8	ND	.19	.07	.06	12000	12800	ND	ND	81.1	18.2	12.4	20.1	42100	27200	ND	ND	641	383	33.6	29.6	102.	75.5	.32	.36	ND		92.1	
	BIN06S	11.2	11.3	ND	.17	.02	.06	8460	7910	ND	ND	81.3	8.8	7.5	15.5	38700	17700	14.8	ND	643	260	32.5	14.9	101.	43.9	ND	.22	ND		ND	
	CIN06S	11.7	12.6	ND	.22	.07	.09	10700	8540	ND	ND	81.5	19.5	5.9	ND	40100	21000	14.1	ND	633	72.2	36.1	ND	96.1	ND	ND	.39	ND		ND	
	AIN06TW	ND	.003	ND	ND	ND	ND	.17	.16	.002	ND	.004	ND	.002	ND	3.7	2.7	.01	ND	.09	.04	.01	ND	.035	ND	ND	ND	ND		ND	
	AIN06RW	ND	.002	ND	ND	ND	ND	.16	.18	ND	ND	.003	ND	ND	ND	2.2	3.8	ND	ND	.05	.06	ND	.01	.030	ND	ND	ND	ND		ND	

AF ENDIX B. Continued je 2)

Site No.	Sample I.D.	As 1988	As 1987	Sb 1988	Sb 1987	Hg 1988	Hg 1987	Al 1988	Al 1987	Cd 1988	Cd 1987	Cr 1988	Cr 1987	Cu 1988	Cu 1987	Fe 1988	Fe 1987	Pb 1988	Pb 1987	Mn 1988	Mn 1987	Ni 1988	Ni 1987	Zn 1988	Zn 1987	Se 1988	Se 1987	Ag 1988	Sn 1988
6	B1N06RW	ND	.002	ND	ND	ND	ND	.08	.16	.001	ND	.003	ND	ND	ND	0.8	2.8	ND	ND	.02	.04	.005	ND	.024	.007	ND	ND	ND	ND
	C1N06RW	ND	.002	ND	ND	ND	ND	.11	.14	.001	ND	.004	ND	.021	ND	1.0	1.8	.01	ND	.03	.03	.017	ND	.029	ND	ND	ND	ND	.01
13	A1N13S	4.60	6.70	ND	.19	.05	.07	12100	14400	ND	1.07	73.4	26.2	11.4	19.5	31100	22900	22.5	ND	527	346	28.7	20.0	94.3	66.2	.31	.28	ND	ND
	B1N13S	2.89	8.77	ND	.19	.20	.08	15900	12300	ND	1.07	73.6	22.4	11.1	14.8	30100	19500	14.6	ND	426	326	33.1	18.2	99.2	59.7	.44	.31	ND	ND
	C1N13S	2.93	7.29	ND	.18	.02	.07	8180	13900	ND	1.3	72.2	22.9	12.6	9.78	29300	21400	22.6	ND	412	378	31.8	19.9	98.8	64.8	.41	.37	ND	ND
	A1N13TW	ND	.001	.02	ND	ND	ND	.56	.39	.002	ND	.005	.004	.006	ND	4.4	3.0	.01	ND	.07	.04	.018	ND	.023	.008	ND	ND	ND	ND
	A1N13RW	ND	ND	ND	ND	ND	ND	.67	.34	ND	ND	.005	.004	.002	ND	5.0	2.4	ND	ND	.07	.03	.005	.010	ND	ND	ND	ND	ND	ND
	B1N13RW	ND	.001	ND	ND	ND	ND	.60	.36	ND	ND	.004	ND	.002	ND	3.7	2.4	ND	ND	.05	.03	ND	ND	ND	ND	ND	ND	ND	ND
	C1N13RW	ND	.002	.02	ND	ND	ND	.70	.38	ND	ND	.004	.003	.003	ND	4.4	4.1	ND	ND	.06	.05	.006	ND	.032	ND	ND	ND	ND	ND
14	A1N14S	8.76	9.54	ND	.15	ND	.05	4140	7480	ND	ND	25.3	14.7	ND	9.5	12300	15300	ND	ND	171	244	8.6	9.71	29.0	20.6	ND	.22	ND	ND
	B1N14S	7.53	13.3	ND	.25	ND	.07	3160	10800	ND	1.03	22.8	20.3	ND	12.7	15400	25300	ND	ND	226	575	13.1	15.6	33.8	54.5	ND	.28	ND	ND
	C1N14S	8.99	17.6	ND	.18	ND	.07	5890	10300	ND	1.31	26.4	20.6	ND	5.8	13400	25100	ND	ND	199	390	11.4	14.4	34.0	48.7	ND	.28	ND	ND
	A1N14TW	ND	.003	ND	ND	ND	ND	.21	.20	ND	ND	.002	.003	ND	ND	3.6	4.2	ND	ND	.09	.09	ND	ND	ND	ND	ND	ND	ND	.02
	A1N14RW	ND	.002	ND	.005	ND	ND	.22	.33	ND	ND	.003	ND	ND	ND	3.0	3.1	ND	ND	.07	.06	ND	.014	.059	ND	ND	ND	ND	ND
	B1N14RW	ND	.003	ND	ND	ND	ND	.22	.21	ND	ND	.004	ND	ND	ND	3.0	2.9	ND	ND	.08	.06	.004	.011	.045	ND	ND	ND	ND	.02
	C1N14RW	ND	.001	ND	ND	ND	ND	.27	.24	.002	ND	.005	.003	ND	ND	4.8	2.6	ND	ND	.13	.05	.013	ND	ND	.008	ND	ND	ND	ND
7	A1N07S	6.92	8.14	ND	.24	.04	.13	6610	10100	ND	ND	97.1	22.3	5.6	19.2	21900	20000	ND	27.6	516	399	45.1	39.2	62.4	57.3	ND	.31	ND	ND
	B1N07S	9.38	16.5	ND	.36	ND	.10	8490	12600	ND	ND	76.2	17.2	2.5	21.2	15200	30800	17.1	ND	382	424	34.3	50.0	46.0	77.3	ND	.38	ND	ND
	C1N07S	10.1	9.77	ND	.24	.03	.15	10500	11600	ND	ND	54.4	35.7	2.8	15.0	18500	15400	ND	29.8	435	355	38.1	47.1	48.4	62.9	ND	.36	ND	ND
	A1N07TW	ND	.002	ND	ND	ND	ND	.09	.25	ND	ND	.003	ND	.003	ND	0.8	0.8	ND	ND	.02	.02	ND	ND	.035	.013	ND	ND	ND	ND
	A1N07RW	ND	ND	ND	ND	ND	ND	.08	.23	.004	ND	.003	ND	ND	ND	0.8	0.9	ND	ND	.02	.02	.006	ND	.027	ND	ND	ND	ND	ND
	B1N07RW	ND	.001	ND	ND	ND	ND	.10	.20	ND	ND	.003	.004	ND	ND	1.4	0.7	ND	ND	.04	.02	ND	ND	.026	.005	ND	ND	ND	ND
	C1N07RW	ND	ND	ND	ND	ND	ND	.11	.24	ND	ND	.003	ND	.002	ND	1.5	0.9	ND	ND	.04	.22	.004	.010	.032	ND	ND	ND	ND	.02
8	A1N08S	4.90	3.7	ND	.15	ND	ND	6260	5500	ND	ND	56.7	18.4	6.2	13.5	17100	13900	ND	ND	426	233	39.1	22.0	46.2	35.0	ND	.05	ND	52.6
	B1N08S	9.11	4.0	ND	.14	ND	ND	10100	5400	ND	ND	32.1	8.9	4.5	8.9	18300	13700	ND	ND	410	238	33.2	28.3	42.5	34.6	.41	.03	ND	ND
	C1N08S	7.21	4.5	ND	.14	.02	ND	9370	4670	ND	ND	29.9	7.8	4.8	8.6	14700	12400	ND	ND	401	179	27.4	16.8	36.5	22.8	ND	.06	ND	ND
	A1N08TW	ND	.002	ND	ND	ND	ND	.06	.04	ND	ND	.002	.006	ND	ND	0.8	1.8	ND	ND	.05	.06	.005	.014	.062	.008	ND	ND	ND	ND
	A1N08RW	ND	.002	2	ND	ND	ND	—	.34	—	ND	—	ND	—	ND	—	1.0	—	ND	—	.03	—	ND	—	ND	ND	ND	—	—
	B1N08RW	ND	.002	ND	ND	ND	ND	.03	.35	ND	ND	.002	ND	ND	ND	0.2	0.9	ND	ND	.01	.03	.005	ND	ND	.014	ND	ND	ND	ND
	C1N08RW	ND	.001	ND	ND	ND	ND	.06	.36	ND	ND	.002	.004	ND	ND	1.0	0.9	ND	ND	.06	.03	ND	ND	.023	ND	ND	ND	ND	ND
9	A1N09S	9.24	3	ND		.13		16500		ND		93.9		19.3		31100		21.5		2320		71.1		104.		1.18		ND	150
	B1N09S	11.5		ND		.02		4890		ND		45.0		10.6		18000		14.8		645		37.2		50.8		.50		ND	ND
	C1N09S	8.0		ND		.03		8270		ND		52.7		11.0		21200		22.0		671		41.3		55.9		ND		ND	37.6
	A1N09TW	ND		ND		ND		.05		ND		.006		ND		0.3		.01		.02		ND		.022		ND		ND	ND
	A1N09RW	ND		ND		ND		.07		.002		.005		.003		0.3		.02		.02		.010		ND		ND		ND	.02
	B1N09RW	ND		ND		ND		.45		ND		.017		.003		0.9		.04		.04		ND		.020		ND		ND	ND
	C1N09RW	ND		ND		ND		.05		ND		.005		ND		0.3		.01		.02		ND		ND		ND		ND	ND

..PPENDIX B. Continued (page 3)

Site No.	Sample ID	As 1988	As 1987	Sb 1988	Sb 1987	Hg 1988	Hg 1987	Al 1988	Al 1987	Cd 1988	Cd 1987	Cr 1988	Cr 1987	Cu 1988	Cu 1987
10	AIN10S	7.1		ND		.08		17600		ND		76.6		18.2	
	BIN10S	9.3		ND		ND		15900		ND		33.8		2.6	
	CW10S	13.5		ND		.07		11400		ND		33.2		4.2	
	AIN10TW	ND		ND		ND		.07		ND		.006		ND	
	AIN10RW	ND		ND		ND		.09		ND		.007		.002	
	BIN10RW	ND		ND		ND		.10		ND		.008		.002	
	CIN10RW	ND		ND		ND		.07		ND		.006		.003	
11	AIN11S	7.2	12.4	ND	.27	.02	.12	4990	16300	ND	1.55	58.8	31.6	8.0	23.7
	BIN11S	7.8	14.9	ND	.34	ND	.12	9730	15700	ND	1.07	30.8	30.0	8.8	21.8
	CIN11S	8.2	13.9	ND	.38	ND	.13	9840	18300	ND	2.75	28.2	35.2	7.4	25.3
	AIN11TW	ND	.003	ND	ND	ND	ND	.33	1.69	ND	ND	.003	.006	.003	ND
	AIN11RW	ND	ND	ND	ND	ND	ND	.37	0.93	ND	ND	.004	.004	ND	ND
	BIN11RW	ND	ND	ND	ND	ND	ND	.37	.85	.002	ND	.005	.004	.003	ND
	CIN11RW	ND	.002	ND	ND	ND	ND	.44	1.59	ND	ND	.004	.006	.003	ND
12	AIN12S	12.2	6.41	ND	.20	.10	ND	13400	11300	ND	0.73	78.1	20.0	31.8	12.3
	BIN12S	12.5	6.75	ND	.19	.19	.04	16100	13200	ND	0.86	82.4	23.7	23.9	20.0
	CIN12S	15.4	5.92	ND	.21	.06	.03	17900	11700	ND	1.08	76.7	20.0	27.4	11.7
	AIN12TW	ND	.001	ND	ND	ND	ND	.54	2.18	ND	ND	.004	.004	ND	ND
	AIN12RW	ND	.001	ND	ND	ND	ND	.63	2.27	ND	ND	.004	ND	ND	ND
	BIN12RW	ND	.003	ND	ND	ND	ND	.88	1.77	ND	ND	.007	.004	.002	ND
	CIN12RW	ND	.002	ND	ND	ND	ND	.37	1.99	ND	ND	.005	.005	ND	ND

Site No.	Sample ID	Fe 1988	Fe 1987	Pb 1988	Pb 1987	Mn 1988	Mn 1987	Ni 1988	Ni 1987	Zn 1988	Zn 1987	Se 1988	Se 1987	Ag 1988	Sn 1988
10	AIN10S	37200		12.2		1630		31.4		90.4		.69		ND	88.7
	BIN10S	23900		15.1		411		15.3		50.6		.38		ND	ND
	CW10S	26300		14.5		549		21.2		53.7		ND		ND	ND
	AIN10TW	1.0		.01		.02		ND		.031		ND		ND	ND
	AIN10RW	1.0		.02		.02		ND		.029		ND		ND	ND
	BIN10RW	1.3		.03		.03		ND		.034		ND		ND	.02
	CIN10RW	1.0		.02		.02		ND		ND		ND		ND	ND
11	AIN11S	24200	29100	13.6	ND	630	547	23.3	27.9	60.9	75.8	ND	.31	ND	1020
	BIN11S	18700	27700	ND	ND	593	558	19.0	24.7	53.6	77.6	ND	.48	ND	ND
	CIN11S	19800	32300	17.9	ND	497	670	16.3	30.0	48.3	88.0	ND	.51	ND	ND
	AIN11TW	2.2	5.0	ND	ND	.08	.19	.004	ND	ND	ND	ND	ND	ND	ND
	AIN11RW	1.5	2.4	ND	ND	.05	.09	ND	.013	ND	.005	ND	ND	ND	ND
	BIN11RW	1.9	2.0	.02	ND	.07	.06	.013	ND	ND	.006	ND	ND	ND	.01
	CIN11RW	2.3	4.6	ND	ND	.09	.18	.004	.016	ND	.010	ND	ND	ND	ND
12	AIN12S	32900	21100	21.1	ND	808	417	37.1	19.3	94.2	56.6	.72	.18	ND	ND
	BIN12S	36400	24400	24.8	ND	704	554	41.1	21.6	103.	67.0	.83	.15	ND	ND
	CIN12S	34700	21300	23.0	ND	760	474	35.4	19.1	89.9	49.9	.64	.16	ND	ND
	AIN12TW	.84	3.0	ND	ND	.02	.06	ND	ND	.034	.006	ND	ND	ND	ND
	AIN12RW	.79	3.2	ND	ND	.01	.06	ND	.014	ND	ND	ND	ND	ND	ND
	BIN12RW	1.79	2.6	ND	ND	.06	.06	.004	ND	ND	.006	ND	ND	ND	ND
	CIN12RW	.42	2.8	ND	ND	.01	.06	ND	ND	ND	.008	ND	ND	ND	ND

Tissue Samples – 1987 only[4]

Site No.	Sample ID	As	Sb	Hg	Al	Cd	Cr	Cu	Fe	Pb	Mn	Ni	Zn	Se
ontrols ish from mined streams)	INNT01	.22	.03	1.1	3.1	ND	.38	ND	3.6	ND	.67	ND	3.7	.26
	INNT02	.21	ND	.63	5.1	ND	.57	ND	3.6	ND	.62	ND	4.0	.25
	INNT03	.13	ND	1.1	3.2	ND	.65	.33	4.7	ND	.37	ND	3.3	.25
xperimentals ish from ned streams)	INNT05	.10	ND	.48	5.0	ND	.51	ND	5.8	ND	.40	ND	4.1	.17
	INNT06	.07	ND	.76	3.9	ND	.46	ND	3.0	ND	.50	ND	4.1	.18
	INNT07	.07	ND	.84	5.4	ND	1.1	4.4	6.9	ND	.56	2.4	6.1	.19
	INNT08	.09	ND	.72	4.6	ND	.60	2.4	7.9	ND	.32	.88	5.0	.18
	INNT09	.04	ND	.63	3.6	ND	.35	.75	3.6	ND	.18	ND	4.2	.13
	INNT10	.18	ND	.78	7.1	ND	.33	.38	4.6	ND	.41	ND	3.7	.22
	INNT04	.14	ND	1.7	1.4	ND	.60	ND	3.2	ND	.38	ND	4.2	.31
	INNT11	.22	ND	1.1	2.2	ND	.28	ND	2.2	ND	.22	ND	3.2	.35
	INNT12	.07	ND	.42	1.3	ND	.31	.41	2.1	ND	.38	ND	4.4	.19

1 ICP Metals analyses; all data are ppm (dry wt.) unless otherwise noted; ND = not detected
2 Data not received from analytical laboratory
3 Stations 9 and 10 were not sampled in 1987
4 All data (ppm, wet wt.) are from northern pike muscle sampled only in 1987